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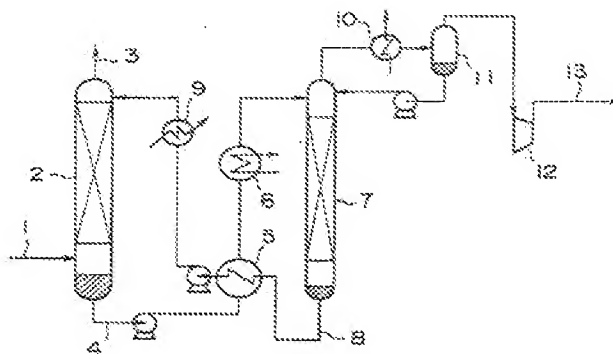
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(54) Process for the removal of highly concentrated carbon dioxide from high-pressure natural gas

(57) This invention relates to a process for removing highly concentrated CO₂ from high-pressure natural gas and recovering it in a high-pressure state.

This process comprises the absorption step of bringing high-pressure natural gas having a CO₂ partial pressure of 2 kg/cm² or greater and a pressure of 30 kg/cm² or greater into gas-liquid contact with a regenerated CO₂-lean absorbing fluid comprising a CO₂ absorbing fluid of which the difference in saturated CO₂ absorption level between 40°C and 120°C is not less than 30 Nm³ per ton of solvent at a CO₂ partial pressure of 2 kg/cm², whereby highly concentrated CO₂ present in the high-pressure natural gas is absorbed into the CO₂-lean absorbing fluid to produce refined natural gas having a reduced CO₂ content and a CO₂-rich absorbing fluid; and the regeneration step of heating the CO₂-rich absorbing fluid without depressurizing it, whereby high-pressure CO₂ having a pressure of 10 kg/cm² or greater is liberated and a CO₂-lean absorbing fluid is regenerated and recycled for use in the absorption step.

FIG. 1



Description

BACKGROUND OF THE INVENTION

1. Field of the invention

This invention relates to a process for the removal of highly concentrated carbon dioxide (CO_2) from high-pressure natural gas. More particularly, it relates to a process for the removal of highly concentrated CO_2 from high-pressure natural gas whereby, at a natural gas production spot or the like, CO_2 is separated and removed from the collected high-pressure natural gas having a pressure of 30 kg/cm² or greater (the term "pressure" as used herein means an absolute pressure) to produce refined natural gas, and whereby the separated CO_2 can be obtained in a relatively high-pressure state which is beneficial for the purpose of injection when it is utilized in tertiary oil recovery or stored permanently in an underground aquifer.

2. Description of the related art

It may usually happen that natural gas produced in a gas field contains an appreciable amount of CO_2 . According to the necessity for reducing the cost required to transport such natural gas from its production spot to a remote consumption place, and for adjusting its calorific value to the standard at the consumption place, some CO_2 is previously removed therefrom to produce refined natural gas having a CO_2 content ranging from 2-3 vol.% to ten-odd vol.%. Conventionally, the CO_2 separated by primary refining at the natural gas production spot or in the neighborhood thereof has seldom been utilized. That is, such CO_2 has been dumped directly into the atmosphere or has rarely been used as an injection gas for tertiary oil recovery in an oil field. Accordingly, little consideration has been given to the pressure of the CO_2 separated by the aforesaid refining process.

In recent years, global warming due to an increase of atmospheric CO_2 has come to be regarded as a problem. Accordingly, the present situation is such that the CO_2 separated in the above-described manner must be pressurized in order to inject it into an underground aquifer for the purpose of permanent storage or to use it positively for the purpose of tertiary oil recovery. However, in spite of the fact that high-pressure natural gas is treated, the CO_2 separated by a conventionally employed process for the removal of CO_2 from natural gas has a low pressure close to atmospheric pressure. This is disadvantageous in that, for the above-described purpose of permanent storage or tertiary oil recovery, the CO_2 must be pressurized from a low pressure close to atmospheric pressure to a pressure of about 150 kg/cm² which is required for injection.

SUMMARY OF THE INVENTION

As a result of intensive investigations on the above-described problems concerning the removal of CO_2 from natural gas and the disposal and utilization of the separated CO_2 , the present inventors have found that, by employing a specific process using, among various absorbing fluids having the ability to absorb CO_2 , an absorbing fluid having so-called physical absorbing power characterized by the marked temperature dependence of saturated CO_2 absorption level, CO_2 having a much higher pressure than that obtained by conventional processes can be separated at low energy cost with much more simplified equipment than used in conventional systems. The present invention has been completed on the basis of this finding.

That is, the present invention provides a method by which carbon dioxide that has conventionally been dumped into the atmosphere during the collection of natural gas can be separated and recovered in a high-pressure state permitting underground dumping in conformance with recent global environmental standards. This method enables the separated carbon dioxide to be dumped into the ground without using a compressor. Alternatively, it also enables the separated carbon dioxide to be returned to the top of an underground oil stratum in an oil field. Thus, the intended object can be accomplished by employing a system of simple construction.

According to the present invention, there is provided a process for the removal of highly concentrated CO_2 from high-pressure natural gas which comprises the absorption step of bringing high-pressure natural gas having a CO_2 partial pressure of 2 kg/cm² or greater and a pressure of 30 kg/cm² or greater into gas-liquid contact with a regenerated CO_2 -lean absorbing fluid comprising a CO_2 absorbing fluid of which the difference in saturated CO_2 absorption level between 40°C and 120°C is not less than 30 Nm³ per ton of solvent at a CO_2 partial pressure of 2 kg/cm², whereby highly concentrated CO_2 present in the high-pressure natural gas is absorbed into the CO_2 -lean absorbing fluid to produce refined natural gas having a reduced CO_2 content and a CO_2 -rich absorbing fluid; and the regeneration step of heating the CO_2 -rich absorbing fluid without depressurizing it, whereby high-pressure CO_2 having a pressure of 10 kg/cm² or greater is liberated and a CO_2 -lean absorbing fluid is regenerated and recycled for use in the absorption step.

After having absorbed CO_2 , the CO_2 absorbing fluid used in the present invention is regenerated in the regeneration step where most of the CO_2 is liberated therefrom, and then recycled for use in the absorption step. In the present

invention, the CO_2 absorption capacity of the aforesaid CO_2 absorbing fluid must be such that the difference in saturated CO_2 absorption level between 40°C and 120°C is not less than 30 Nm^3 per ton of solvent, preferably not less than 40 Nm^3 per ton of solvent, at a CO_2 partial pressure of 2 kg/cm^2 . Usually, if the temperature and CO_2 partial pressure of a specific absorbing fluid are determined, the saturated CO_2 absorption level shows a definite value based on the saturated CO_2 absorption curve for the specific absorbing fluid, almost regardless of the type of the CO_2 -containing gas. In the present invention, CO_2 is removed from high-pressure natural gas having a pressure of 30 kg/cm^2 or greater by absorbing it into a CO_2 -lean absorbing fluid obtained by regenerating the CO_2 absorbing fluid in the succeeding regeneration step, and the resulting CO_2 -rich absorbing fluid is heated without substantially depressurizing it, so as to liberate CO_2 therefrom. Accordingly, it is preferable to use an absorbing fluid which can absorb CO_2 easily at a relatively low temperature and a lower CO_2 partial pressure than in the regeneration step, and can liberate CO_2 easily when heated in the regeneration step, i.e., at a relatively high temperature and a relatively high CO_2 partial pressure.

The temperature dependence of the saturated CO_2 absorption level of an absorbing fluid depends largely on the types of the chemical agent(s) and solvent constituting the absorbing fluid. In the present invention, the difference in saturated CO_2 absorption level between 40°C and 120°C at a certain CO_2 partial pressure (i.e., a CO_2 partial pressure of 2 kg/cm^2) is employed as an index to the ability of an absorbing fluid to absorb CO_2 in the absorption step and liberate CO_2 when heated in the regeneration step. Thus, there is used an absorbing fluid of which the difference in saturated CO_2 absorption level between 40°C and 120°C at a CO_2 partial pressure of 2 kg/cm^2 is not less than 30 Nm^3 per ton of solvent and preferably not less than 40 Nm^3 per ton of solvent. No particular limitation is placed on the type of the absorbing fluid, provided that its difference in saturated CO_2 absorption level between 40°C and 120°C at the aforesaid CO_2 partial pressure is not less than 30 Nm^3 per ton of solvent and it is stable at the heating temperature of the regeneration step. Moreover, when the CO_2 partial pressure is 2 kg/cm^2 , the saturated CO_2 absorption level at 40°C serves as an index to the CO_2 absorption capacity of the CO_2 -lean absorbing fluid. In the present invention, it is preferable to use an absorbing fluid of which this absorption level is not less than 30 Nm^3 per ton of solvent and more preferably not less than 40 Nm^3 per ton of solvent.

Specific examples of the aforesaid absorbing fluid include an aqueous solution of N-methyldiethanolamine (MDEA), an aqueous solution of triethanolamine, and an aqueous solution of potassium carbonate, as well as these solutions having a CO_2 absorption promoter (e.g., piperazine) added thereto.

When it is desired to absorb and remove highly concentrated CO_2 present in natural gas and thereby obtain the separated CO_2 in a high-pressure state suitable for use in tertiary oil recovery or for the underground storage of CO_2 , the process of the present invention has the advantage of simplifying the equipment and reducing the energy cost.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates an exemplary system which can be employed to carry out the process for the removal of CO_2 from high-pressure natural gas in accordance with the present invention; and

FIG. 2 illustrates an exemplary system which can be employed to carry out a conventional process for the removal of CO_2 from high-pressure natural gas.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

An exemplary system which can be employed to carry out the process of the present invention is specifically described below with reference to FIG. 1. For purposes of comparison, an exemplary system which has conventionally been employed is illustrated in FIG. 2.

In FIG. 1, reference numeral 1 designates natural gas; 2, an absorption tower; 3, refined natural gas; 4, a CO_2 -rich absorbing fluid; 5, a heat exchanger; 6, a heater; 7, a regeneration tower; 8, a CO_2 -lean absorbing fluid; 9, a cooler; 10, an overhead condenser; 11, a separating drum; 12, a compressor; and 13, high-pressure CO_2 . By way of example, the conditions for removing CO_2 from natural gas by employing the system of FIG. 1 and using a 45 wt.% aqueous solution of MDEA as absorbing fluid are given below. Natural gas 1 having a CO_2 content of 26 vol.%, a pressure of 58 kg/cm^2 and a temperature of 25°C is fed to the lower part of an absorption tower 2. This absorption tower 2 is packed, for example, with an irregular packing material so that the ascending natural gas will come into efficient gas-liquid contact with a CO_2 -lean absorbing fluid fed to the upper part thereof. The refined natural gas 3 having been freed of CO_2 by contact with the CO_2 -lean absorbing fluid, which now has a CO_2 content of 2 vol.%, a temperature of 50°C and a pressure of 58 kg/cm^2 , is discharged from the top of absorption tower 2. On the other hand, the CO_2 -lean absorbing fluid having absorbed CO_2 turns into a CO_2 -rich absorbing fluid 4, which is transferred to a regeneration step by means of a pump and regenerated therein.

The regeneration step essentially comprises a heat exchanger 5, a heater 6 and a regeneration tower 7. CO_2 -rich absorbing fluid 4 is heated in heat exchanger 5 by heat exchange with a hot CO_2 -lean absorbing fluid 8 which will be described later, further heated with heater 6 using steam as a heat source, and then fed to regeneration tower 7. The purpose of regeneration tower 7 is to separate CO_2 , which has been liberated by the aforesaid heating, from the

absorbing fluid to produce a CO₂-lean absorbing fluid. Although an additional heater such as a reboiler is not required, it may be installed as desired. The liberated CO₂ is cooled in overhead condenser 10 and separated from any entrained absorbing fluid in a separating drum 11. This CO₂, which has a relatively high pressure of 55 kg/cm² at about 40°C, is compressed to a pressure of 150 kg/cm² by means of a compressor 12. The resulting high-pressure CO₂ is used for purposes of tertiary oil recovery or stored in the earth.

On the other hand, the CO₂-lean absorbing fluid 8 withdrawn from the bottom of regeneration tower 7, which has a temperature of about 140°C, is cooled in heat exchanger 5 by heating CO₂-rich absorbing fluid 4 as described above, further cooled with a cooler 9 using cooling water, seawater or the like, and then recycled to the upper part of absorption tower 2.

Now, the above-described process for the removal of CO₂ from high-pressure natural gas in accordance with the present invention is compared with a conventional system illustrated in FIG. 2. In FIG. 2, the units and elements having the same functions as those shown in FIG. 1 are designated by the same reference numerals. In the system of FIG. 2, natural gas 1 is fed in the same manner as in FIG. 1, and CO₂ is absorbed and removed therefrom under the same conditions as in FIG. 1. The resulting gas is discharged from the top of absorption tower 2 as refined natural gas 3. On the other hand, the resulting CO₂-rich absorbing fluid 4 is withdrawn by means of a pump and then flashed in a first flash drum 21 to produce the liberated CO₂ 32 and the absorbing fluid having a reduced CO₂ content. The latter is further heated with a heater 22 and fed to a second flash drum 23 where it is flashed again. The liberated CO₂ 33 is recovered by way of an overhead condenser 24 and a first separating drum 25. Since the CO₂ liberated in second flash drum 23 has approximately atmospheric pressure, it is compressed with a first compressor 26 and combined with the aforesaid liberated CO₂ 32. The combined CO₂ is passed through a second separating drum 27, a second compressor 28, a third separating drum 29 and a third compressor 30 to obtain high-pressure CO₂ 31 having a pressure of about 150 kg/cm². On the other hand, the CO₂-lean absorbing fluid 8 obtained at approximately atmospheric pressure is pressurized with a pressurizing pump and cooled with a cooler 24 to produce a CO₂-lean absorbing fluid 8', which is fed to the upper part of absorption tower 2.

It is evident from a comparison of FIGs. 1 and 2 that, in order to obtain the liberated CO₂ having an identical pressure of 150 kg/cm², the process of the present invention illustrated in FIG. 1 brings about a marked simplification of equipment. In particular, it can be seen that the number of compressors involving a rotary driving mechanism requiring troublesome operational management can be largely decreased. Moreover, in the case where the aforesaid aqueous solution of MDEA is used as absorbing fluid, the amounts of energy required for both systems have been calculated from the saturated CO₂ absorption curve for the absorbing fluid, and the results thus obtained are summarized in Table 1. The thermal efficiency of power units is supposed to be 25%.

Table 1

| | FIG. 1 (Example) | FIG. 2 (Comparative Example) |
|---|--------------------|------------------------------|
| Feed rate of natural gas (Nm^3/h) (25°C ; $58 \text{ kg}/\text{cm}^3$; CO_2 content, 26 vol.%) | 37,852 | 37,852 |
| Discharge rate of refined natural gas (Nm^3/h) (50°C ; $57.8 \text{ kg}/\text{cm}^3$; CO_2 content, 2 vol.%) | 28,310 | 28,310 |
| Circulation rate of absorbing fluid (T/h) | 555 | 555 |
| Total flow rate of liberated CO_2 (Nm^3/h) | 9,542 | 9,542 |
| CO_2 pressure at the outlet of first compressor (kg/cm^2) (Compressor power, kW) | ----- | 4.8 (450) |
| CO_2 pressure at the outlet of second compressor (kg/cm^2) (Compressor power, kW) | ----- | 30 (937) |
| CO_2 pressure at the outlet of third compressor (kg/cm^2) (Compressor power, kW) | ----- | 150 (695) |
| CO_2 pressure at the outlet of compressor 12 (kg/cm^2) (Compressor power, kW) | 150 (181) | ----- |
| Power other than CO_2 compressor power (kW) | 80 | 1,159 |
| Total power (kW) | 261 | 3,241 |
| Total quantity of heat used to heat CO_2 -rich absorbing fluid (Kcal/h) | 10.5×10^6 | 1.07×10^6 |
| Total power calculated by converting the quantity of heat into power (kW) (thermal efficiency $\eta = 25\%$) | 3,313 | 3,552 |

Claims

1. A process for a removal of highly concentrated carbon dioxide from high-pressure natural gas which comprises an absorption step of bringing high-pressure natural gas having a carbon dioxide partial pressure of $2 \text{ kg}/\text{cm}^2$ (absolute pressure) or greater and a pressure of $30 \text{ kg}/\text{cm}^2$ (absolute pressure) or greater into gas-liquid contact with a regenerated carbon dioxide-lean absorbing fluid comprising a carbon dioxide absorbing fluid of which a difference in saturated carbon dioxide absorption level between 40°C and 120°C is not less than 30 Nm^3 per ton of solvent at a carbon dioxide partial pressure of $2 \text{ kg}/\text{cm}^2$ (absolute pressure), whereby highly concentrated carbon dioxide present in the high-pressure natural gas is absorbed into the carbon dioxide-lean absorbing fluid to produce refined natural gas having a reduced carbon dioxide content and a carbon dioxide-rich absorbing fluid; and a regeneration step of heating the carbon dioxide-rich absorbing fluid without depressurizing it, whereby high-pressure carbon dioxide having a pressure of $10 \text{ kg}/\text{cm}^2$ (absolute pressure) or greater is liberated and a carbon dioxide-lean absorbing fluid is regenerated and recycled for use in said absorption step.
2. A process for a disposal of highly concentrated carbon dioxide present in high-pressure natural gas which comprises an absorption step of bringing high-pressure natural gas having a carbon dioxide partial pressure of $2 \text{ kg}/\text{cm}^2$ (absolute pressure) or greater and a pressure of $30 \text{ kg}/\text{cm}^2$ (absolute pressure) or greater into gas-liquid contact with a regenerated carbon dioxide-lean absorbing fluid comprising a carbon dioxide absorbing fluid of which a difference in saturated carbon dioxide absorption level between 40°C and 120°C is not less than 30 Nm^3 per ton of solvent at a carbon dioxide partial pressure of $2 \text{ kg}/\text{cm}^2$ (absolute pressure), whereby highly concentrated carbon dioxide present in the high-pressure natural gas is absorbed into the carbon dioxide-lean absorbing fluid to produce refined natural gas having a reduced carbon dioxide content and a carbon dioxide-rich absorbing fluid; and a regeneration step of heating the carbon dioxide-rich absorbing fluid without depressurizing it, whereby high-pressure carbon dioxide having a pressure of $10 \text{ kg}/\text{cm}^2$ (absolute pressure) or greater is liberated and dumped into a ground, and a carbon dioxide-lean absorbing fluid is regenerated and recycled for use in said absorption step.

3. A process for a disposal of highly concentrated carbon dioxide present in high-pressure natural gas which comprises an absorption step of bringing high-pressure natural gas having a carbon dioxide partial pressure of 2 kg/cm² (absolute pressure) or greater and a pressure of 30 kg/cm² (absolute pressure) or greater into gas-liquid contact with a regenerated carbon dioxide-lean absorbing fluid comprising a carbon dioxide absorbing fluid of which a difference in saturated carbon dioxide absorption level between 40°C and 120°C is not less than 30 Nm³ per ton of solvent at a carbon dioxide partial pressure of 2 kg/cm² (absolute pressure), whereby highly concentrated carbon dioxide present in the high-pressure natural gas is absorbed into the carbon dioxide-lean absorbing fluid to produce refined natural gas having a reduced carbon dioxide content and a carbon dioxide-rich absorbing fluid; and a regeneration step of heating the carbon dioxide-rich absorbing fluid without depressurizing it, whereby high-pressure carbon dioxide having a pressure of 10 kg/cm² (absolute pressure) or greater is liberated and returned to a top of an underground oil stratum, and a carbon dioxide-lean absorbing fluid is regenerated and recycled for use in said absorption step.
4. A system for separating highly concentrated CO₂ from high-pressure natural gas to produce high-pressure CO₂ which comprises an absorption tower for bringing an ascending flow of natural gas fed to the lower part thereof into gas-liquid contact with a CO₂-lean absorbing fluid fed to an upper part thereof, so as to produce a CO₂-rich absorbing fluid and refined natural gas; heating means for heating the CO₂-rich absorbing fluid; a regeneration tower for separating the CO₂ liberated by heating from the CO₂-rich absorbing fluid to regenerate a CO₂-lean absorbing fluid; separation means for separating the CO₂ from any entrained absorbing fluid; compression means for compressing the CO₂ separated from the entrained absorbing fluid; and cooling means for cooling the CO₂-lean absorbing fluid and recycling it to the upper part of said absorption tower.

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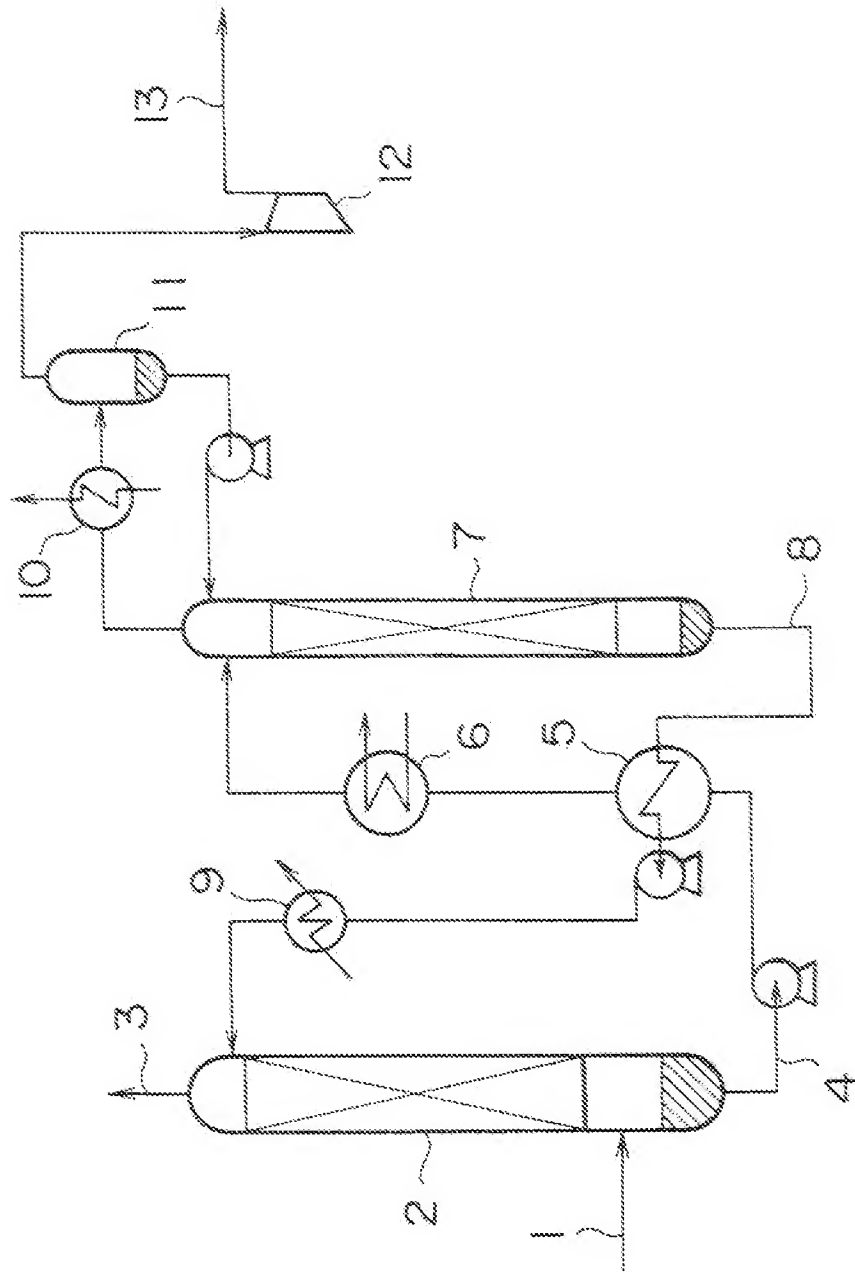
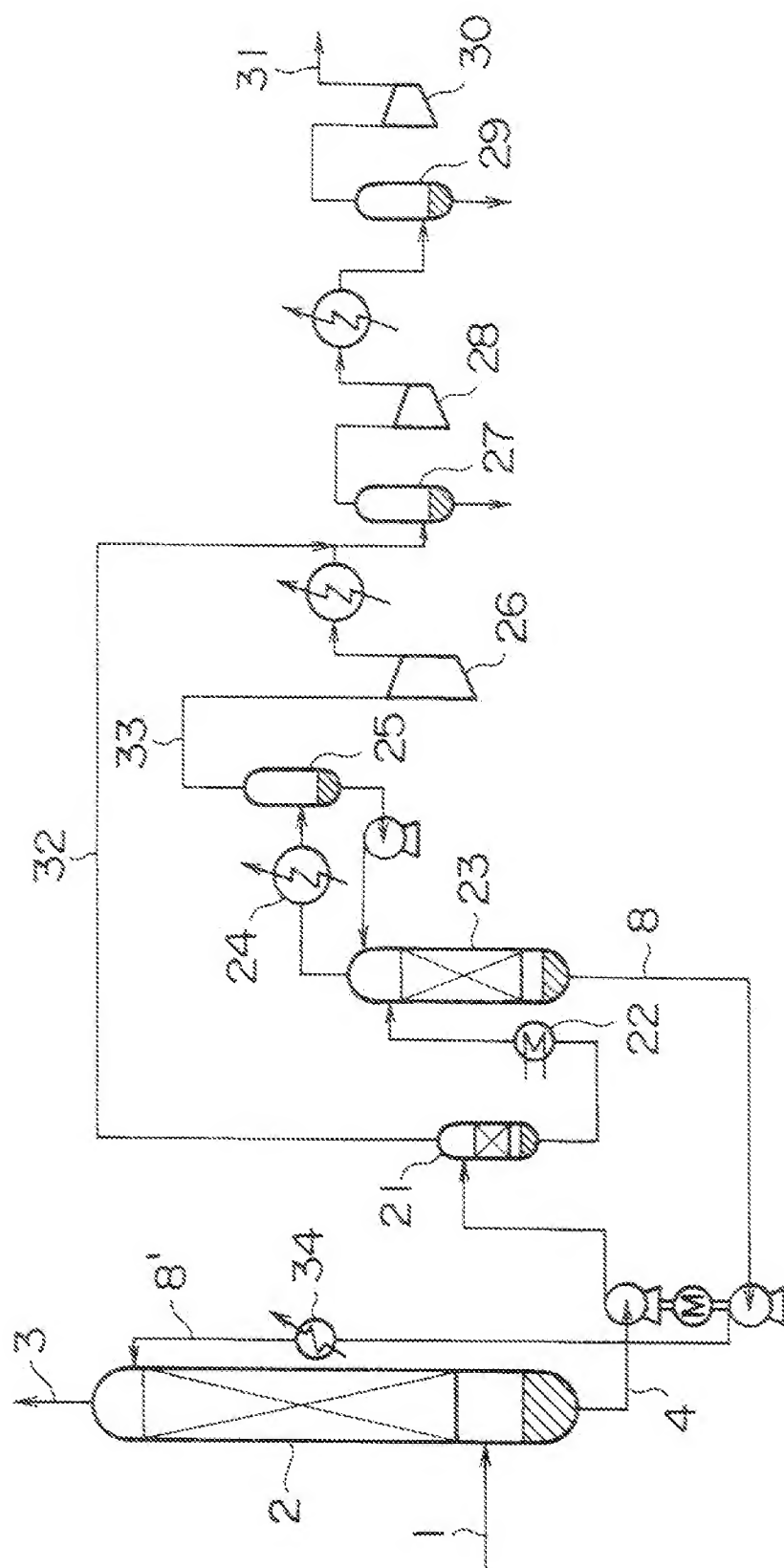


FIG. 2





European Patent
Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 11 2162

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|---|---|--|--|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl. 8) |
| A | US 3 642 430 A (BENSON FIELD AND EPES) * claims 1-3 * | 1-4 | C10L3/10 |
| A | US 4 853 012 A (SOCIETE NATIONALE ELF AQUITAINE) * claims 1,3 * | 1-4 | |
| | | | TECHNICAL FIELDS SEARCHED (Int. Cl. 8) |
| | | | C10L C07C |
| The present search report has been drawn up for all claims | | | |
| Place of search | | Date of completion of the search | Examiner |
| THE HAGUE | | 9 January 1997 | De Herdt, O |
| CATEGORY OF CITED DOCUMENTS | | | |
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